

## Specification



### Sensor and Method for the Production Thereof

This invention relates to a sensor, for example a gas sensor, acceleration sensor, or pressure sensor, with components containing silicon, by means of which electrical signals can be read when analytes are present or in case of mechanical deformation, and a production method.

The moisture in the air forms a thin film of water on the surface of the material containing silicon, which leads to increased surface conductivity. The leakage currents from this increase represent a problem with regard to stability and signal quality for many sensors that are in contact with air.

To prevent the effects of moisture on sensor systems, they are presently encapsulated if possible. If contact with the surrounding air is urgently necessary for the principle of the sensor, for example gas sensors, there is recourse to passive water-repellent membranes. Heating to temperatures well above 100 °C solves the problem as well, but this is associated with considerable expenditure of energy.

The goal of the invention is to make available a sensor with a semiconductor body whose moisture sensitivity and leakage current are substantially reduced. A production method is also to be described.

These goals are achieved by the particular combination of features of Claim 1 and Claim XXX. Beneficial refinements of the invention are found in the subclaims.

The invention is based on the knowledge that the method of silanization familiar

from glass coating can also be applied to semiconductor technology. In this case, a monolayer of the hydrophobic molecular chains in question that suppress the adsorption of water molecules is formed on the surface containing silicon. All hydrophobic molecular chains that participate in a stable bond with the surface are suitable for this. Thus, no continuous water film that favors the unwanted surface conductivity can form, up to high atmospheric humidity levels – almost 100%.

Structural elements containing silicon can operate in ambient air after silanization without heating or encapsulation, without the problem of interference from surface currents induced by moisture.

In general terms, the semiconductor body used as the base in this silicon technology is silanized. Either pure silicon or silicon compounds present superficially can be treated.

The fields of use of such semiconductor sensors based on silicon and insensitive to moisture, for example, are gas sensors, pressure sensors, or in general any sensors that come into contact with essentially atmospheric moisture when in operation. Hence analytes such as target gases are detected by gas sensors, and mechanical shape changes are detected by pressure sensors or acceleration sensors.

Exemplary embodiments will be described below with reference to the schematic drawings, which do not limit the invention.

Figure 1 shows a comparison of a silanized hydrogen sensor and one with no

hydrophobic covering layer,

Figure 2 shows an illustration for various humidity levels and additional gases,

Figure 3 shows the prior art in the form of a floating gate FET.

The functional principle of silanization on silicon nitride and oxidized polycrystalline silicon was tested specifically on a gas sensor, a floating gate field effect transistor (FGFET), and was studied closely. Other embodiments of FETs can also be used, for example suspended gate FETs. Figure 3 shows schematically the structure of the FGFETs used.

### Functional principle

The potential change occurring on the sensitive layer from gas impingement is fed to the MOSFET by the voltage divider extending between the floating gate and capacitive well (electrode), and leads there to a current change between drain D and source S. The floating electrode is covered with a nitride or oxide layer to protect it against interfering leakage current. Nevertheless, potentials can still be coupled in capacitively through a conducting moisture film on this passivation. To prevent this, an equipotential surface, the so-called guard ring, is placed on the surface around the sensitive gate. At higher atmospheric humidity levels ( $> 50\%$ ), increased surface currents nevertheless occur, which lead to severe signal drift. To prevent this, it is necessary to prevent the formation of a moisture film. Very hydrophobic molecular chains are then applied to the existing passivation by silanization before the hybrid gate is mounted. Since the adhesive bond of the gate then no longer adheres to this layer, additional aluminum-adhesive pads are necessary on the chip, since the silanization does not adhere there. Because of this process, the unheated gas sensors thus produced are almost completely stable

even at high humidity levels. Subsequent measurement shows a comparison between a silanized hydrogen sensor and an untreated one at various humidity levels (see Figure 1).

The sharp drift and "distortion" of the hydrogen signals is effectively suppressed by silanization. The remaining small moisture steps in the silanized signal are caused by the dipole signal of water on the sensitive platinum layer and no longer interfere.

To gain precise information on surface conductivity, the above FGFET was put together with surfaces with no hybrid gate, both silanized and unsilanized. To measure the very small currents qualitatively, use was made of the sensitivity of the floating gate. The guard ring was controlled in both chips with a square-wave generator and the moisture-dependent coupling to the transistors was measured. A very low frequency was chosen (0.1 Hz) to preclude frequency-dependent effects in the RC circuits. The higher the surface conductivity, the larger is the coupling of the square-wave generator into the transistor. The depiction of Figure 2 shows a comparison of these measurements with various humidity levels and additional gases. The current in the transistors is kept constant by feedback electronics. The resulting signals originate from the feedback control circuit and thus show the potential applied to the floating gate.

It can be seen that all moisture effects have disappeared after silanization. The remaining coupling is then only capacitive. The reaction of the nitride to  $\text{NO}_2$  has disappeared in the silanized version. Increased sensitivity to  $\text{NH}_3$  shows up instead. This is to be expected with the trichlorosilane used as the starting material for silanization,

especially n-octadecyltrichlorosilane, since alkalis like ammonia attack the bonds to the nitride passivation. On the other hand, the layer is especially stable to acids (like  $\text{NO}_2$ ). The samples with oxidized polysilicon show the same behavior.